

The University of Chicago

A RAY TRACK APPARATUS FOR THE
STUDY OF ALPHA, BETA,
AND COSMIC RAYS

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE PHYSICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF CHEMISTRY
1932

By
DONALD ALBIN WALLACE

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A Wilson cloud chamber is a device which renders visible the paths of alpha and beta particles, and effects associated with X, gamma, and cosmic rays. The design of such a chamber depends upon the purposes for which it is to be used. The apparatus to be described in this report has been designed for precise work, and for automatic operation over long periods of time.

The chamber itself resembles that devised by C. T. R. Wilson¹ twenty years ago. His photographs have never been excelled, but his apparatus was not designed for continuous operation. A modification of this apparatus, which could be operated automatically and which made use of two cameras instead of one, was devised by Shimizu.² This latter modification of the cloud chamber was adapted to the study of the stability of atomic nuclei by Harkins and Ryan,³ Harkins and Shadduck,⁴ Blackett,⁵ and Harkins and Schuh.⁶ Definite evidence of the nature of the process of disintegrative-synthesis in nitrogen was obtained by these workers. Other applications of the cloud chamber to work on various problems have been made by Holoubek,⁷ Petrova,⁸ Curtiss,⁹ Locher,¹⁰ Mott-Smith and Locher,¹¹ Skobelzyn,¹² Kapitza,¹³ Meitner and Freitag,¹⁴ and others.

One of the most interesting of problems relating to the structure of the atomic nucleus may be studied with this chamber. Calculations of the rest-mass of the O^{17} nucleus formed in the disintegrative-synthesis of oxygen and hydro-

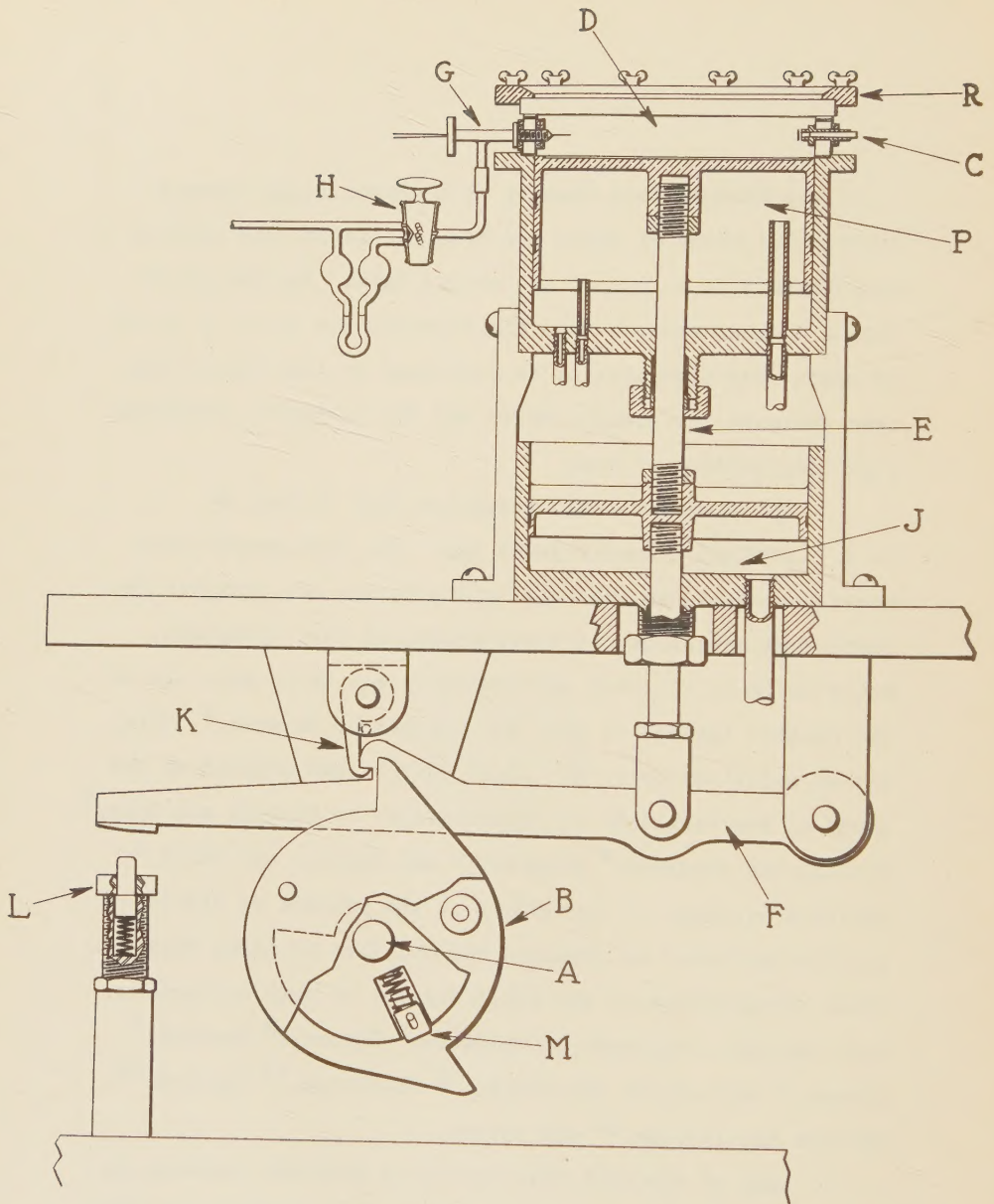


Figure 1

gen from nitrogen and helium have given three sets of values between which there is a constant difference.^{15,16} Since these calculations are based on only seven sets of data, more disintegrative-syntheses are needed in order to prove whether the data used in the calculations are correct, and to discover whether the three masses correspond to three different quantum states of the nucleus, or if one or more of these is fictitious.

Another problem is the study of cosmic rays in the cloud chamber. Mott-Smith and Locher,¹¹ Skobelzyn,¹² Bothe and Kolhorster,¹⁷ and Rossi¹⁸ have published the results of work which indicates that the nature of the cosmic radiation is as yet unknown.

A modified Wilson cloud chamber has been used in this laboratory for the last ten years to study atomic nuclei.^{3,4,6} Although excellent results have been obtained with the apparatus which has been used here in the past, it was thought advisable to build a larger one which would be more accurate and which could operate at pressures above and particularly below atmospheric pressure.

The new apparatus consists essentially of a glass cloud chamber seventeen centimeters in diameter and about two centimeters deep, and of devices used to cool the gas in the chamber, to admit alpha particles, to illuminate the chamber, to take the photographs, and to accurately time each opera-

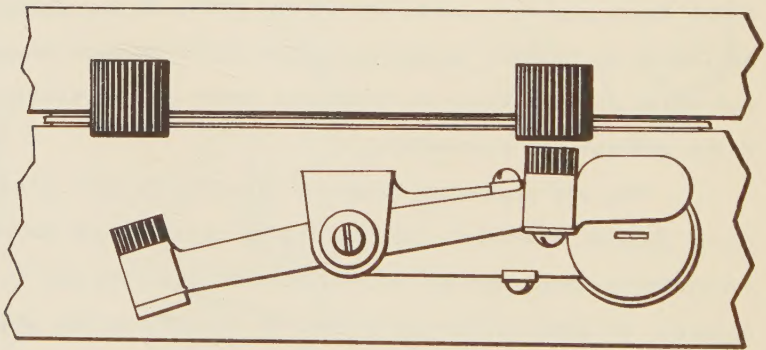
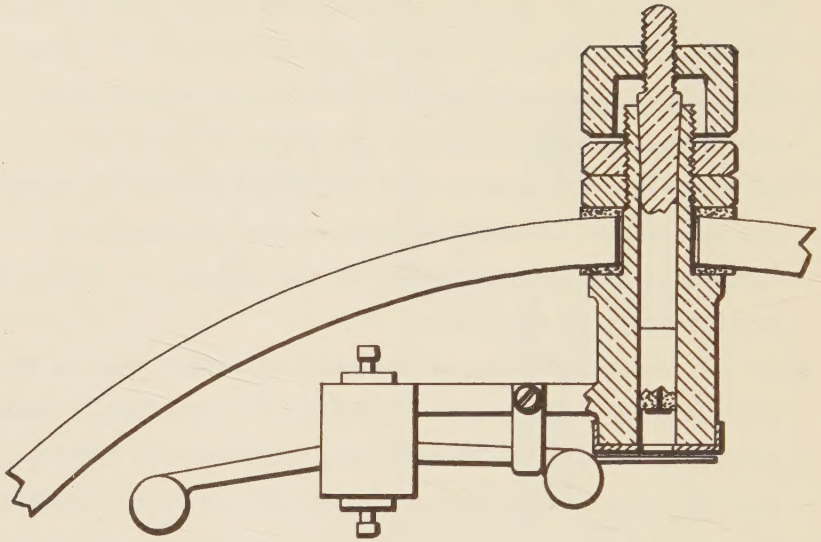


Figure 2

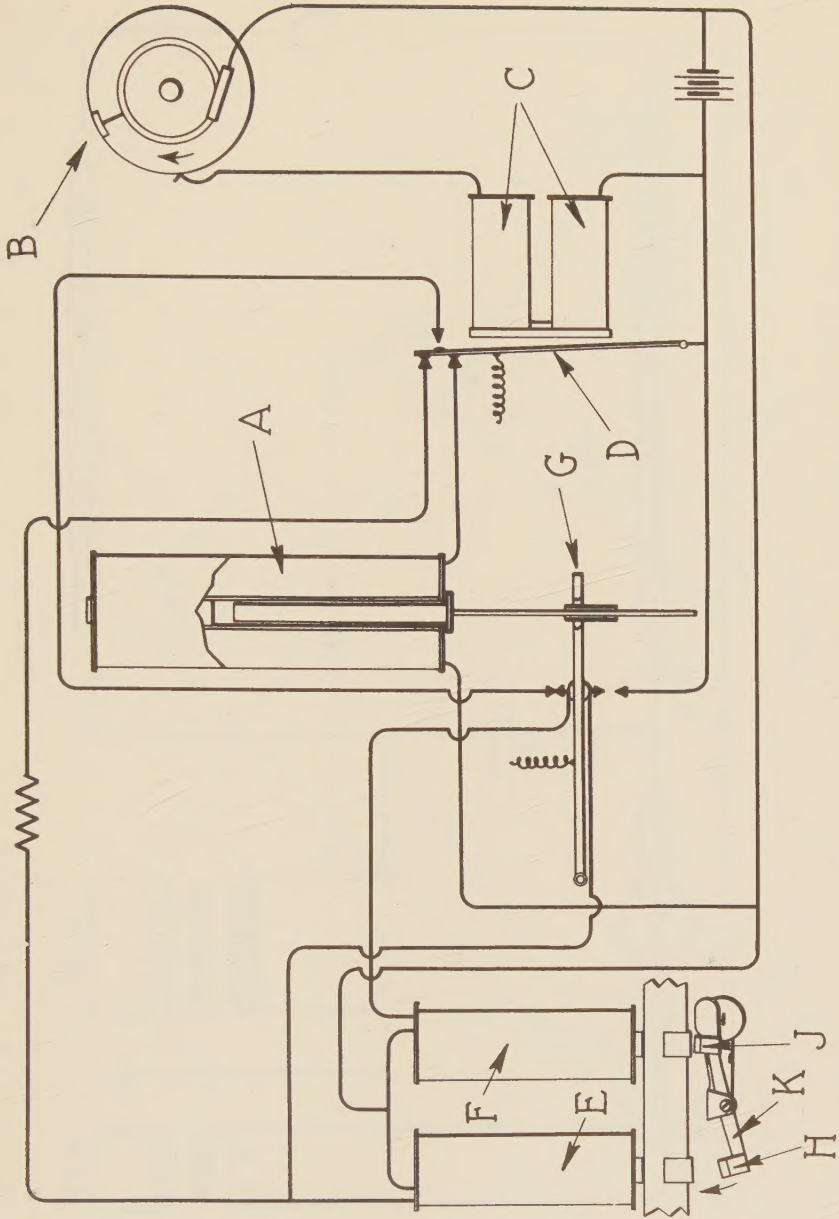


Figure 3

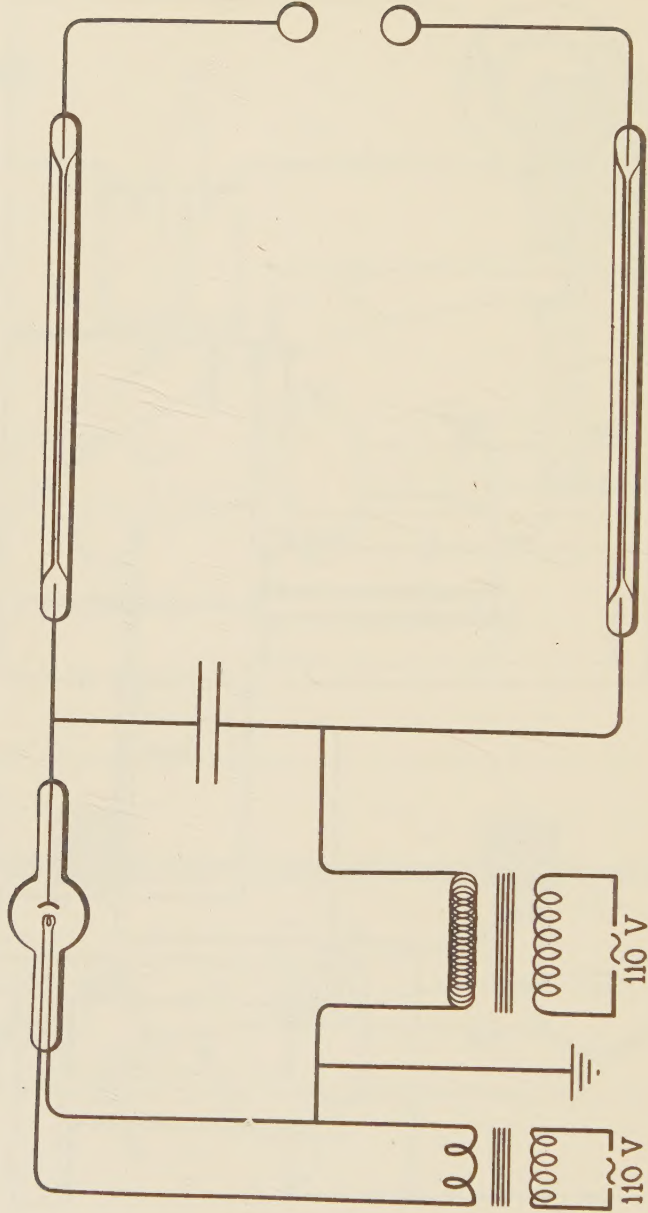


Figure 4

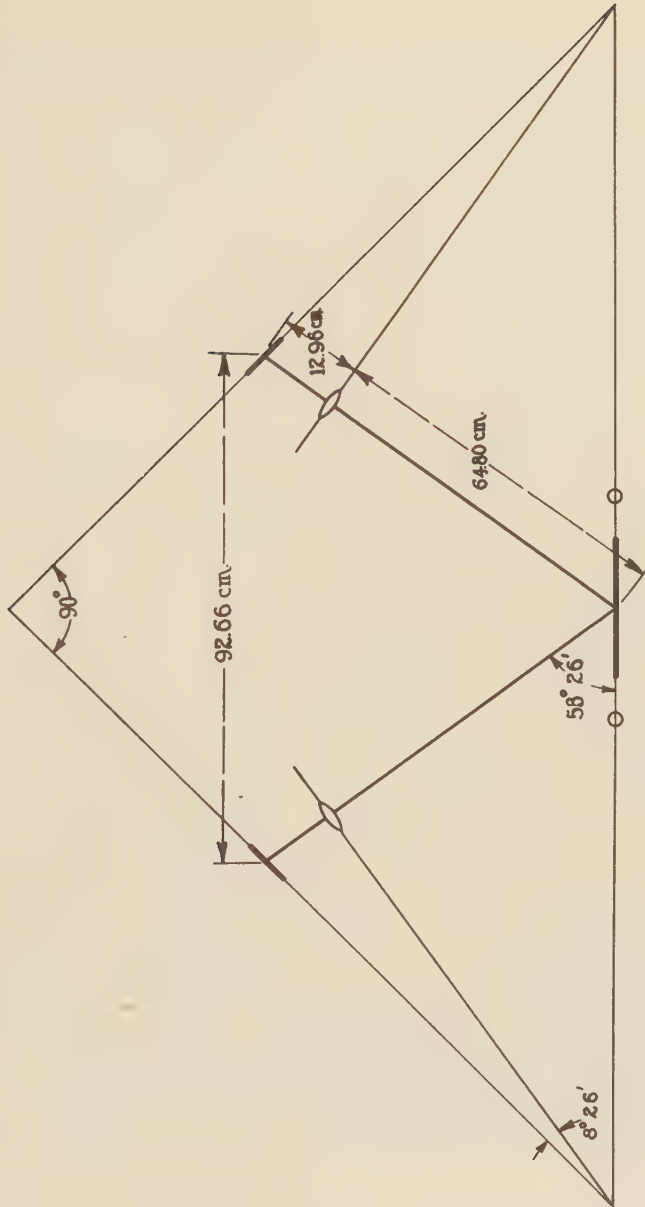


Figure 5

tion. The apparatus may be described by considering it under four heads: (1) A mechanism (Figure 1) which expands the air in the cloud chamber at regular intervals, and which serves as the basis for the timing of the moving parts, (2) a shutter (Figures 2 and 3) which admits the rays whose tracks are to be photographed, (3) lights (Figure 4) which illuminate the tracks, and (4) two cameras and their special lens system (Figure 5). In the context which follows, the apparatus will be discussed under these four headings.

A radioactive source is inserted through a hole in the wall of the chamber (D, Figure 1) at (C). The shutter covers the source, and lies just inside the chamber. The floor of the chamber, which is the top of the upper piston, is covered with an aqueous gel of gelatin blackened with lamp black. The main shaft (A) turns at a constant speed of four revolutions per minute. The cam (B) turns with the main shaft. The connecting rod (E) which controls the movement of the two pistons and the trip-lever (F) is rigid.

In the operation of the apparatus, the chambers (D and P) are filled with gas at the desired pressure, and the chamber (J) is evacuated to about one centimeter of mercury pressure. The pressure of the atmosphere on the top of the lower piston constantly forces both pistons down as far as they will go. Suppose the drive shaft to start in a counter-clockwise direction. Let us follow the action of the

expansion mechanism from the drawing. The cam trips the catch (K), and the trip-lever falls until it strikes an adjustable stop (L). This produces what is called the "long" expansion of the gas in the cloud chamber. The shutter immediately admits the rays which cause tracks to form in the atmosphere of the chamber, which is now cooled and supersaturated with water vapor. The lights flash and the picture is taken.

After two seconds, the cam lifts the trip-lever back onto the catch, restoring the gas in the chamber (D) to its original pressure. Three seconds later the catch is tripped again by the cam. This time the trip-lever is stopped short by a metallic stop (M) backed by a spring on the cam. The purpose of this "short" expansion is to cause water vapor to condense on the fine droplets which remain in the atmosphere of the chamber after the long expansion. The weight of such droplets is thereby increased sufficiently to cause them to settle out and leave the chamber clear for the long expansion. A clear chamber with a background free from fog is essential to the production of good tracks. The pistons remain down for five seconds during the short expansion because the trip-lever slides on a track in the cam until it is lifted back to the catch in preparation for the long expansion. The use of such a double expansion is recommended by C. T. R. Wilson.¹

A thermojunction for the determination of the temperature of the gas extends into the expansion chamber through a

hole drilled along the axis of the valve (G) needle. To test the chamber for leaks, the valve is opened, and the stop-cock (H) is turned through ninety degrees in the left-handed direction. If the chamber leaks, the levels in the butyl phthalate-filled U-tube will become unequal.

The chamber (D) is assembled as follows: A gasket of thin dam rubber is placed in a groove on the upper lip of the upper cylinder and a glass ring two centimeters tall by seventeen centimeters inside diameter whose upper and lower surfaces are ground plane and parallel is placed on the gasket. A second rubber gasket is placed on top of the ring, and a tin-foil gasket is laid upon that. The cover glass completely covers the chamber thus formed. A heavy brass ring (R) which is connected to the cylinder lip by twelve long screws equally spaced serves to hold the parts firmly together. The tin-foil ring, which is insulated from the chamber, is connected to one terminal of a three hundred-volt battery. The rest of the apparatus and the other terminal of the battery are grounded. The field thus established across the chamber is regulated by a commutator, which times the interval which includes the long expansion during which the field is turned off.

It is important that the glass ring used in the assembly of the expansion chamber be strong and optically clear, as well as that it be of the proper size. Such rings

were cut from bell jars. More than a dozen fifteen-inch jars of approximately the correct diameter were examined. Three of these were selected and four rings of very nearly the same dimensions were obtained from them. The cylinders and pistons were built to fit the glass rings.

The trip-lever, connecting rods, cam, drive-shaft, stop (L), and supports for the upper cylinder are of steel. The table top and the supports and bearings for the trip-lever and drive shaft are of cast iron. The cylinders are of yellow brass, lined with copper to prevent alpha rays from the brass from entering the chamber, and the pistons are of red brass. The top of the upper piston is also heavily copper plated to screen out alpha particles. The pistons are fitted with felt rings, and fit the cylinders with a tolerance of less than one thousandth of an inch. The expansion mechanism is mounted on a concrete pier, while the other parts rest ultimately upon the concrete floor of the room. Thus the vibrations due to the expansions do not jar the cameras and other instruments.

The shutter (Figure 2) lies entirely within the expansion chamber. It is operated by an electrical and magnetic system (Figure 3) which lies entirely outside the chamber. A solenoid (A) holds a soft iron rod suspended in its core until contact is made through a commutator (B) which is on the main shaft of the expansion mechanism. This commuta-

tor completes the circuit through the electromagnets (C) and the lever (D) is attracted to them. This breaks the circuits through the solenoid (A) and the "closing" magnet (E), while it closes the circuit through the "opening" magnet (F). During the time which the rod requires to fall and depress the contact lever (G), which is held up against the force of gravity by a spring, the shutter remains open. When the contact lever is forced down, the circuit through the opening magnet is broken, and a circuit through the closing magnet is completed. This closes the shutter, which remains closed until the commutator completes another revolution.

Since the magnetic field acts through the cover glass of the chamber upon two soft iron pieces (H and J) attached to an aluminium lever arm (K), it is unnecessary to have mechanical connection between the inside and outside of the chamber while the apparatus is in operation. Two more pieces of soft iron are set into the cover glass directly above the shutter lever arm in order to shorten the magnetic circuit. In other forms of the cloud chamber apparatus it is usually necessary to use an external shutter, or to operate the shutter mechanically through the wall or cover of the chamber. In the latter case a gas-tight packing-box or a flexible diaphragm, together with other devices inside the chamber is necessary. Small leaks and surges in the atmosphere of the chamber when the long expansion occurs are the

result. The tracks are very easily distorted by such surges, and it is true of most cloud chambers that only the central portion is sufficiently quiet to produce good tracks. Difficulties of this sort are largely eliminated in the new design.

The most difficult part of the construction of the apparatus has been the search for suitable lights. It is desirable that the chamber be illuminated from two opposite sides. Straight horizontal capillary arcs are therefore best suited, provided they have sufficient intensity, since their light can be focused upon the tracks by simple cylindrical lenses or mirrors. The light which is now in use (Figure 4) is a straight pyrex capillary twenty centimeters in length, with a tungsten lead in each end, and filled with air at a pressure of two millimeters of mercury. Argon, helium, or neon may be preferable to air. If consideration is given to the plane which includes the center of each lens (Figure 5) and the center of the expansion chamber, the lights are in a position such that the axis of each capillary is perpendicular to and is bisected by the plane. The lights are level with the chamber and about three inches distant from it.

A mechanically operated rotating arm causes a conductor to pass through the spark gap (Figure 4) almost immediately after the tracks form in the expansion chamber.

By this means, the circuit through the lights is completed, and the condensed discharge produces a brilliant flash of very short duration. The potential across the condensers is about thirty-five thousand volts. Photographs of the spectrum of the light emitted were taken with a Hilger quartz spectrograph, using a Wratten panchromatic plate. It should be remembered that the lights are made of pyrex. The spectra photographed under these conditions were continuous and of moderately uniform intensity in the region from about three thousand Angstrom units to about sixty-eight hundred Angstrom units of wave length. Similar lights have been used in studies of the far ultra-violet.¹⁹ Dr. J. J. Hopfield suggested that they could be used in cloud chamber work.

The photographic system (Figure 5) permits the entire plane of the chamber to be focused accurately upon the plane of the film, even though the two planes are not parallel.²⁰ The lens is tilted with respect to both the object and the image planes. The distances and angles are shown in the figure. Simple optical considerations show the arrangement to be qualitatively correct. The photographs obtained are actually in excellent focus. The cameras are of the standard Universal type, fitted with f/4.5 Taylor-Hobson-Cooke Aviar lenses in special mountings. Eastman panchromatic motion picture film has been used in the preliminary work.

When a collision of an alpha particle with another

nucleus is recorded, and the angles between the tracks, or the relations in their intensities indicate that a disintegration may have taken place, it is necessary to resolve the paths of the colliding particles into a single plane, in order to measure the angles involved precisely. On the same table with the expansion apparatus is a device for holding a large photographic plate at any angle in space. The two films on which the event in question is recorded are placed in the cameras, which are moved on rails so that the plateholder occupies the same position relative to them which the expansion chamber formerly occupied. A ground glass screen is placed in the holder, which is adjusted to the position in space which causes the images of the forked track from both cameras to exhibit exact coincidence. The room is then darkened, a photographic plate is placed in the holder instead of the glass screen, and the image of the collision is projected on the plate. This method was suggested by Dr. A. v. Hippel.⁹

The source of the alpha radiation is the active deposit of thorium, which is electrically collected from radiothorium on a section of platinum wire one-half millimeter in diameter and three millimeters long, placed transversely in the bakelite tip of a copper plug (Figure 2) about three centimeters in length. Contact between the copper and the platinum is made by a platinum wire inserted through

a fine hole through the bakelite. The plug is tapered to fit into a hole in the wall of the expansion chamber just behind a slit which is covered by the shutter. When the plug is in place, the platinum wire tip is parallel to the slit, and in the same horizontal plane with it. The slit is the same size as the exposed cross-section of the wire, and is about three millimeters ahead of it. This arrangement gives a shallow but wide fan of tracks.

Several hundred photographs of alpha particle tracks in air at atmospheric pressure were taken. These show shorter tracks which are due to thorium C, and longer ones which are from thorium C'.

Summary

A new cloud chamber has been constructed for use in the study of disintegrative-syntheses and other atomic and subatomic phenomena. The essential features of the new apparatus are described under four heads:

- 1) An expansion chamber seventeen centimeters in diameter and about two centimeters deep, together with a mechanism which produces the expansions automatically, and which times the other moving parts of the apparatus.

- 2) A new type of electromagnetically operated and timed shutter which admits alpha rays to the chamber at accurately determined intervals.

3) An apparatus for producing brilliant and accurately timed flashes of light to illuminate the ray tracks.

4) A photographic system by means of which the events which occur in the expansion chamber are recorded simultaneously on two films at right angles to each other, and a device for reprojecting photographs of forked tracks.

Photographs of alpha ray tracks in air at atmospheric pressure have been taken. These indicate clearly the ranges of the alpha particles from thorium C and thorium C'.

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